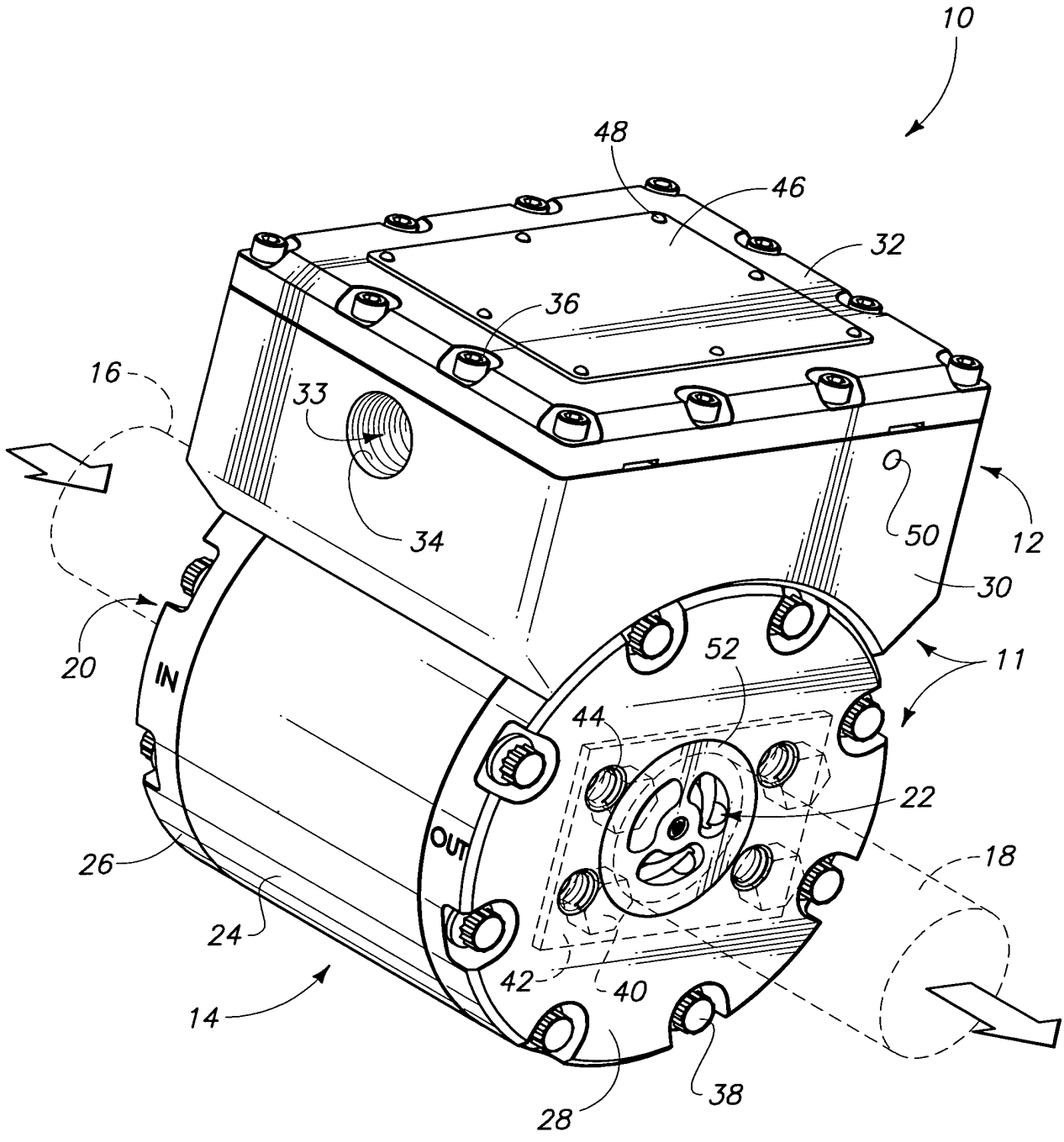
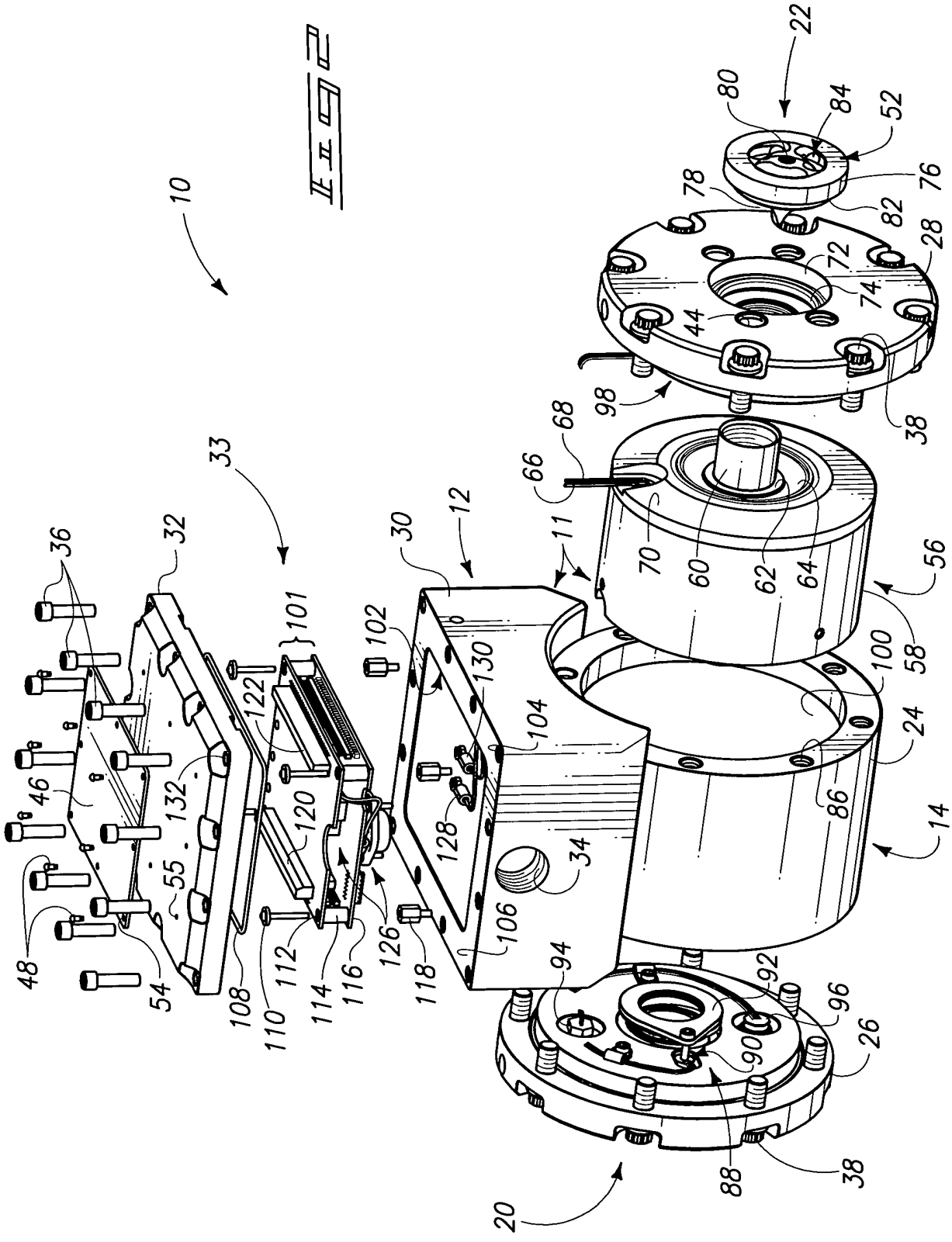

10
48
46
32
36
16
33
34
50
12
30
20
IN
52
11
44
22
26
OUT
18
24
42
40
14
28
38

Fig 1

FIG 2


10
22
80
84
52
78
76
82
28
72
74
44
98
38
68
66
33
12
30
11
70
60
62
64
56
58
100
24
86
14
36
32
101
102
130
104
122
46
132
120
128
34
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106
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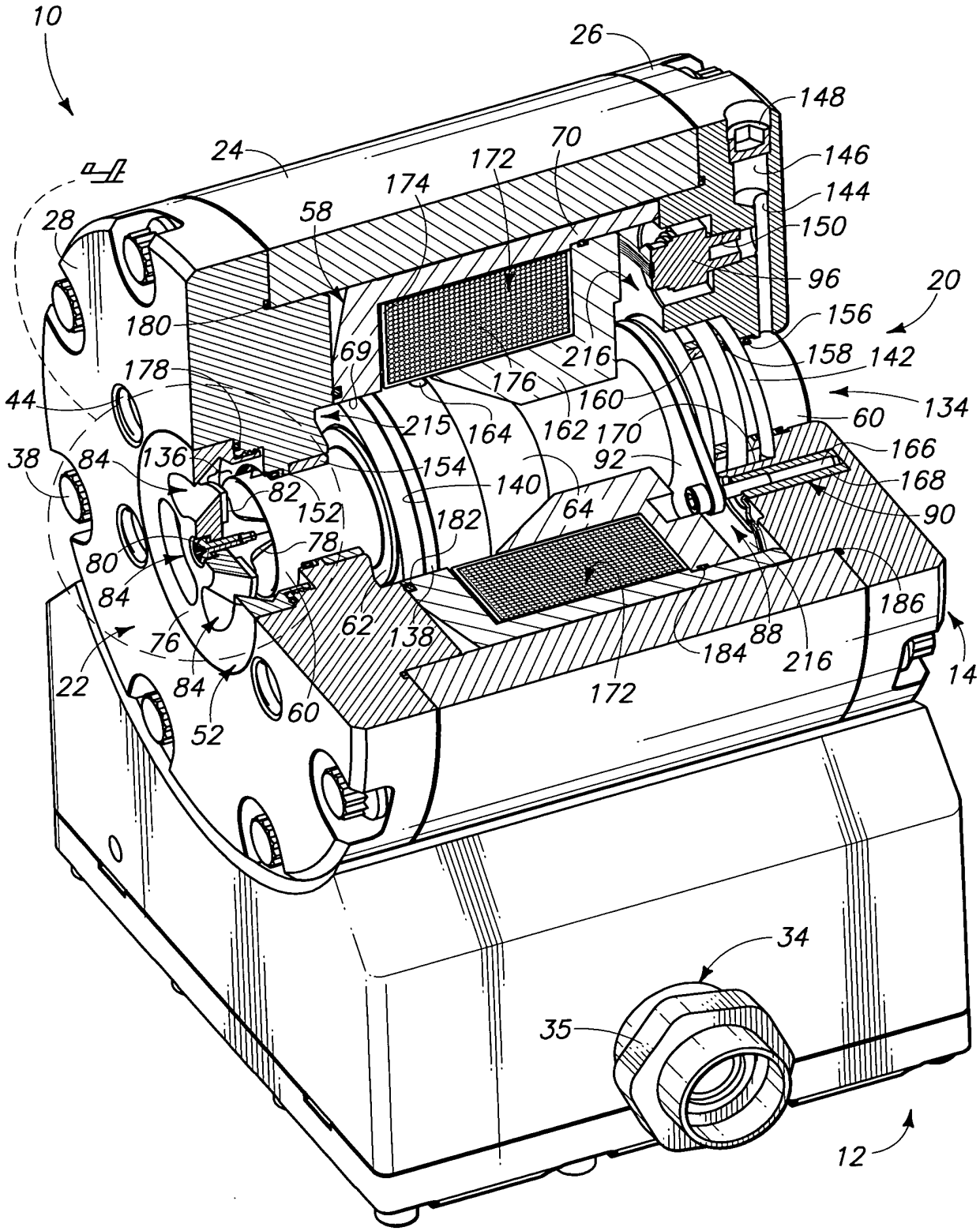
54
108
110
112
114
116
126
118
94
92
96
90
26
88
38
20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26
148
24
70
172
146
174
144
58
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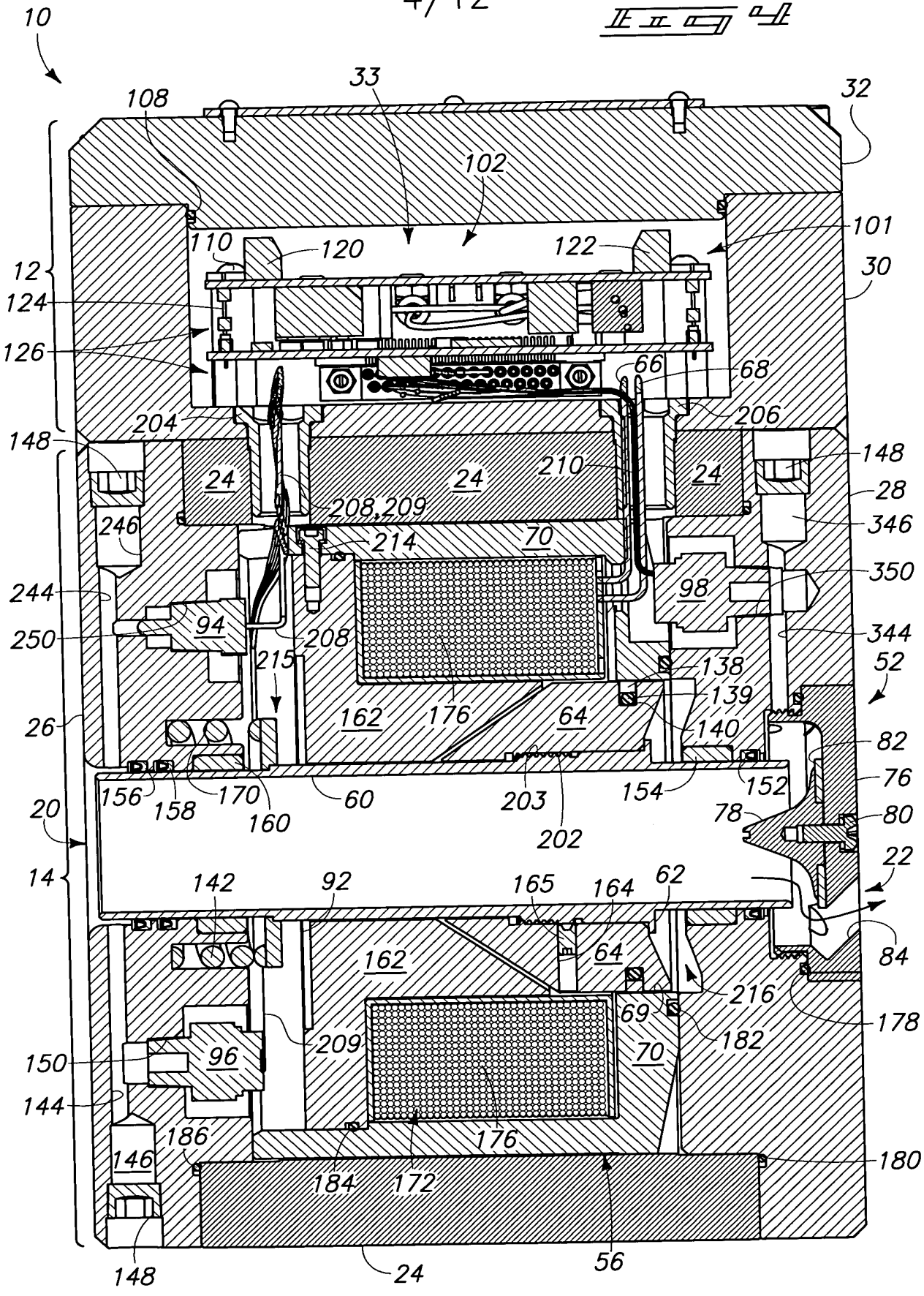
150
96
20
180
156
69
216
158
142
178
176
160
134
44
215
164
162
170
60
38
84
136
154
92
166
140
168
82
152
64
90
182
78
80
84
186
62
138
88
184
216
14
76
172
22
84
60
52
34
35
12

Fig 3

Fig 4


10
33
108
32
102
101
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120
122
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30
124
126
66
68
204
206
148
24
210
208,209
214
70
246
28
346
244
98
350
94
250
208
344
215
138
52
139
26
162
176
64
140
82
156
158
170
160
60
203
202
154
152
76
20
78
80
14
142
92
165
164
62
22
84
162
64
216
69
178
209
182
150
96
70
144
186
176
146
184
172
180
148
24
56

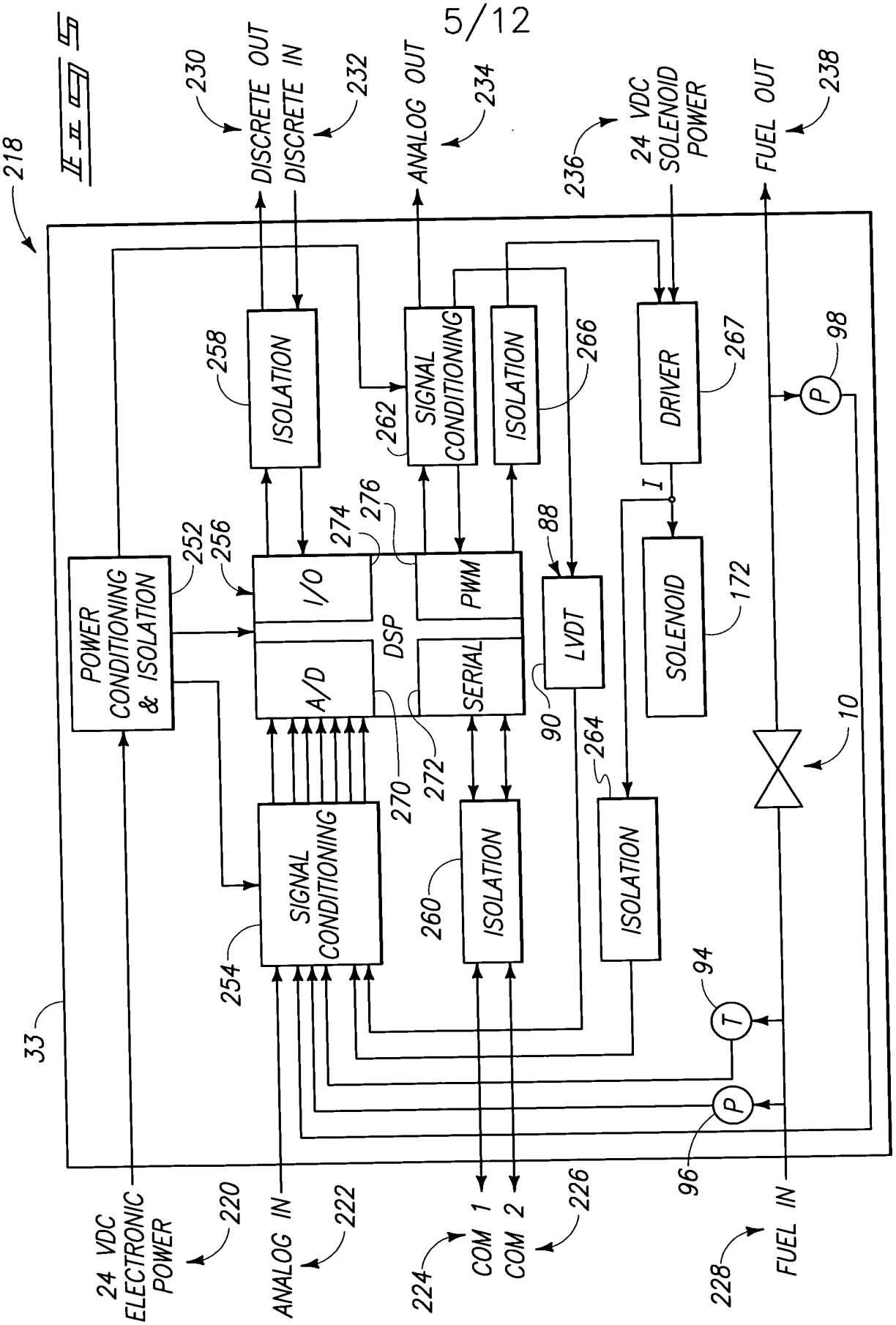


FIG 5
218
DISCRETE OUT
DISCRETE IN
230
232
ANALOG OUT
234
24 VDC SOLENOID POWER
236
FUEL OUT
238
ISOLATION
258
SIGNAL CONDITIONING
262
ISOLATION
266
DRIVER
267
98
POWER CONDITIONING & ISOLATION
252
256
I/O
274
276
PWM
DSP
A/D
SERIAL
88
LVDT
90
SOLENOID
172
I
10
264
270
272
SIGNAL CONDITIONING
254
ISOLATION
260
ISOLATION
94
T
P
96
33
24 VDC ELECTRONIC POWER
220
ANALOG IN
222
224
COM 1
COM 2
226
228
FUEL IN

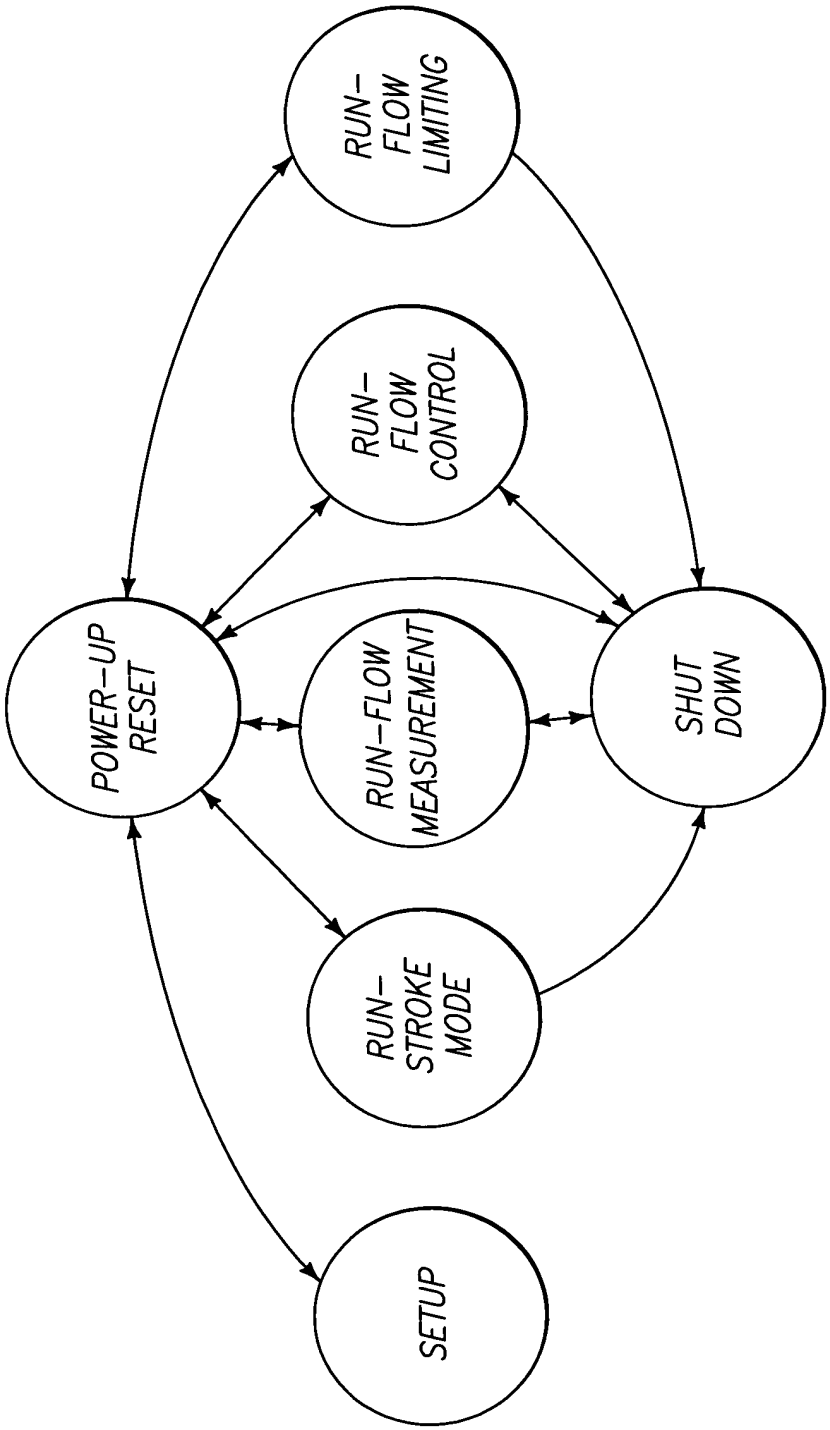

RUN-
FLOW
LIMITING
RUN-
FLOW
CONTROL
POWER-UP
RESET
RUN-FLOW
MEASUREMENT
SHUT
DOWN
RUN-
STROKE
MODE
SETUP

FIG 6

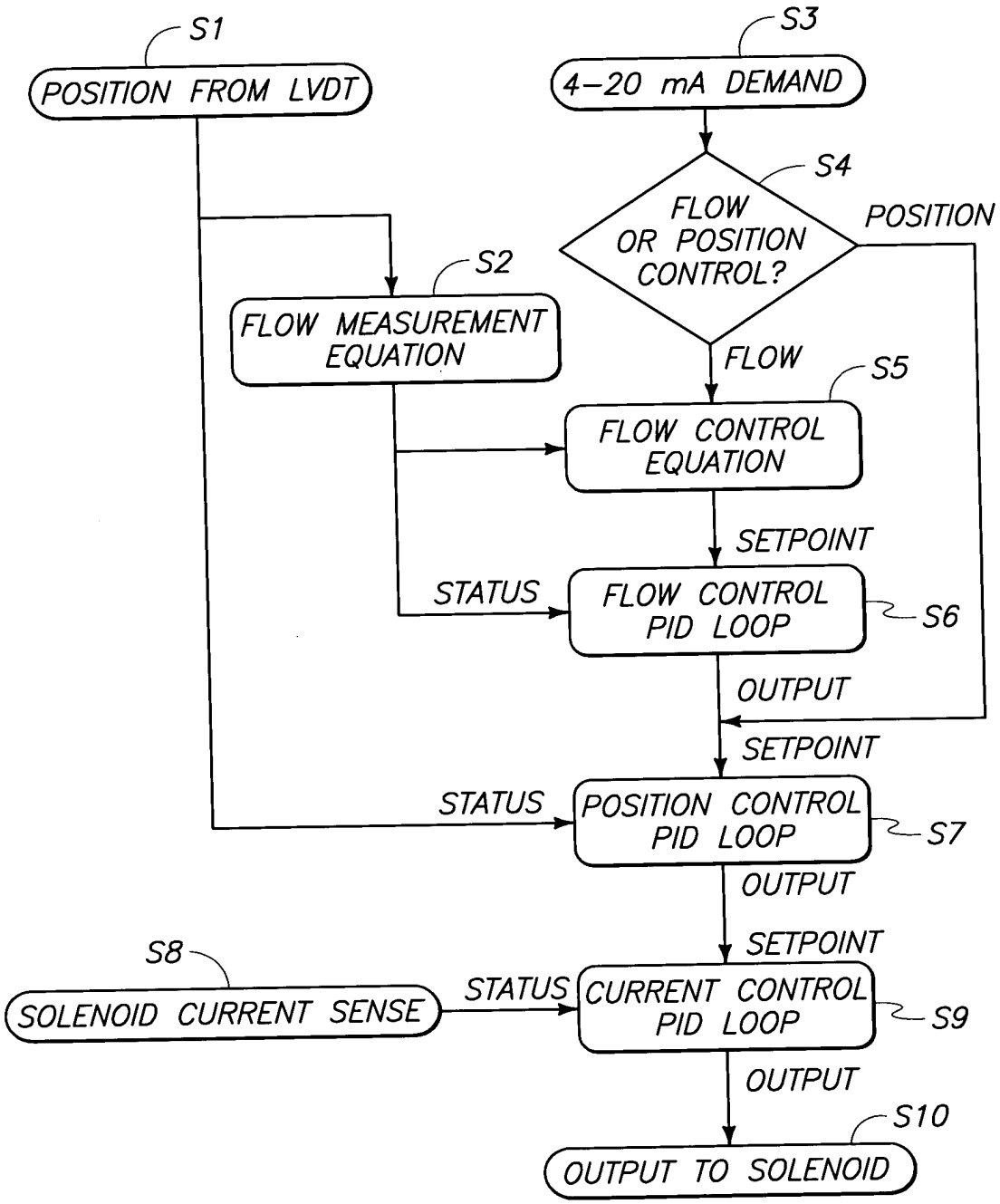

S1
POSITION FROM LVDT
S3
4-20 mA DEMAND
S4
FLOW OR POSITION CONTROL?
POSITION
S2
FLOW MEASUREMENT EQUATION
FLOW
S5
FLOW CONTROL EQUATION
SETPOINT
STATUS
FLOW CONTROL PID LOOP
S6
OUTPUT
SETPOINT
STATUS
POSITION CONTROL PID LOOP
S7
OUTPUT
SETPOINT
S8
SOLENOID CURRENT SENSE
STATUS
CURRENT CONTROL PID LOOP
S9
OUTPUT
S10
OUTPUT TO SOLENOID

Fig 1

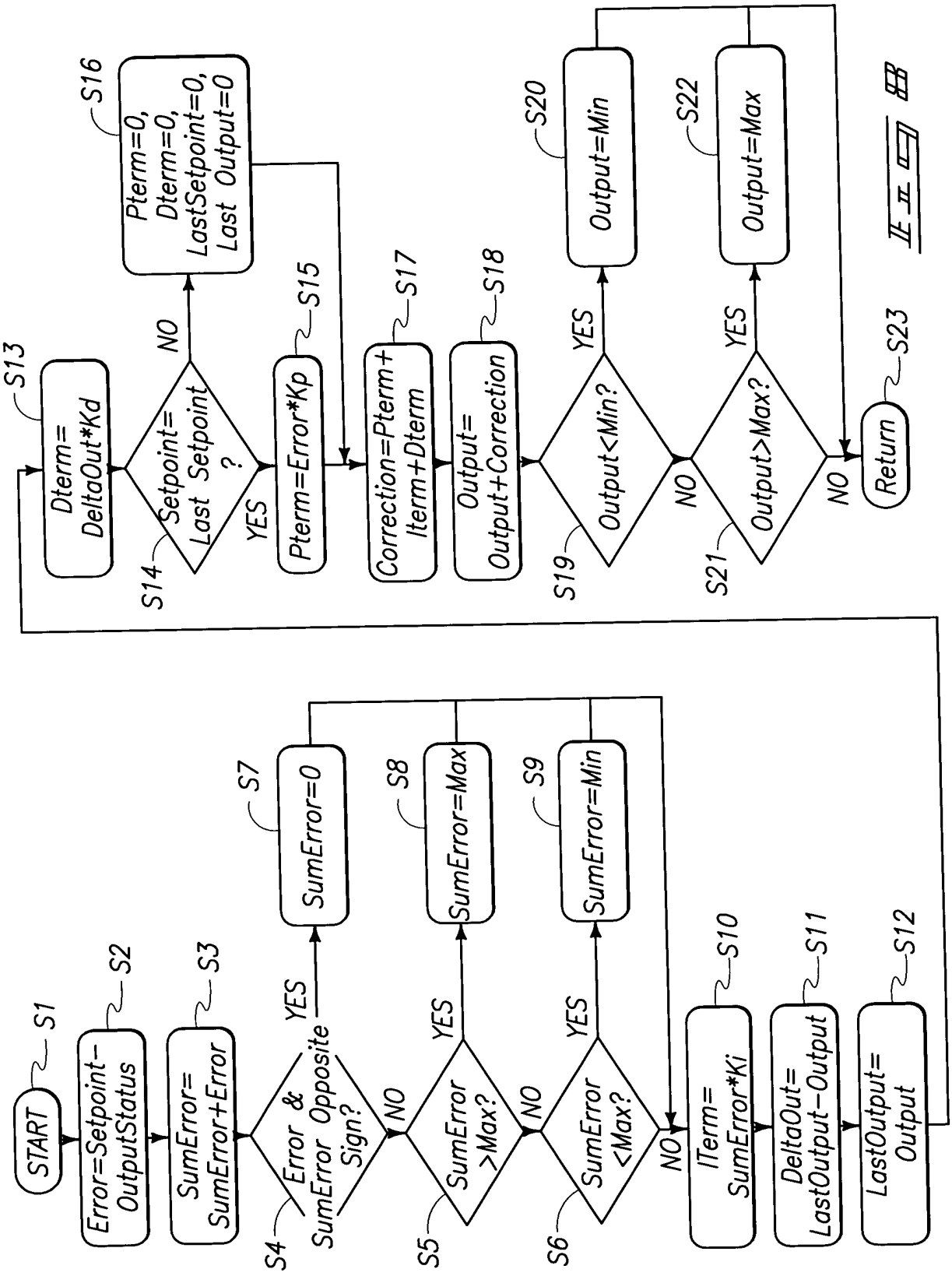

START
S1
Error=Setpoint-OutputStatus
S2
SumError=SumError+Error
S3
Error & SumError Opposite Sign?
S4
YES
SumError=0
S7
NO
SumError >Max?
S5
YES
SumError=Max
S8
NO
SumError <Max?
S6
YES
SumError=Min
S9
NO
ITerm=SumError*Ki
S10
DeltaOut=LastOutput-Output
S11
LastOutput=Output
S12
Dterm=DeltaOut*Kd
S13
Setpoint=Last Setpoint ?
S14
NO
Pterm=0, Dterm=0, LastSetpoint=0, Last Output=0
S16
YES
Pterm=Error*Kp
S15
Correction=Pterm+Iterm+Dterm
S17
Output=Output+Correction
S18
Output<Min?
S19
YES
Output=Min
S20
NO
Output>Max?
S21
YES
Output=Max
S22
NO
Return
S23

Fig 8

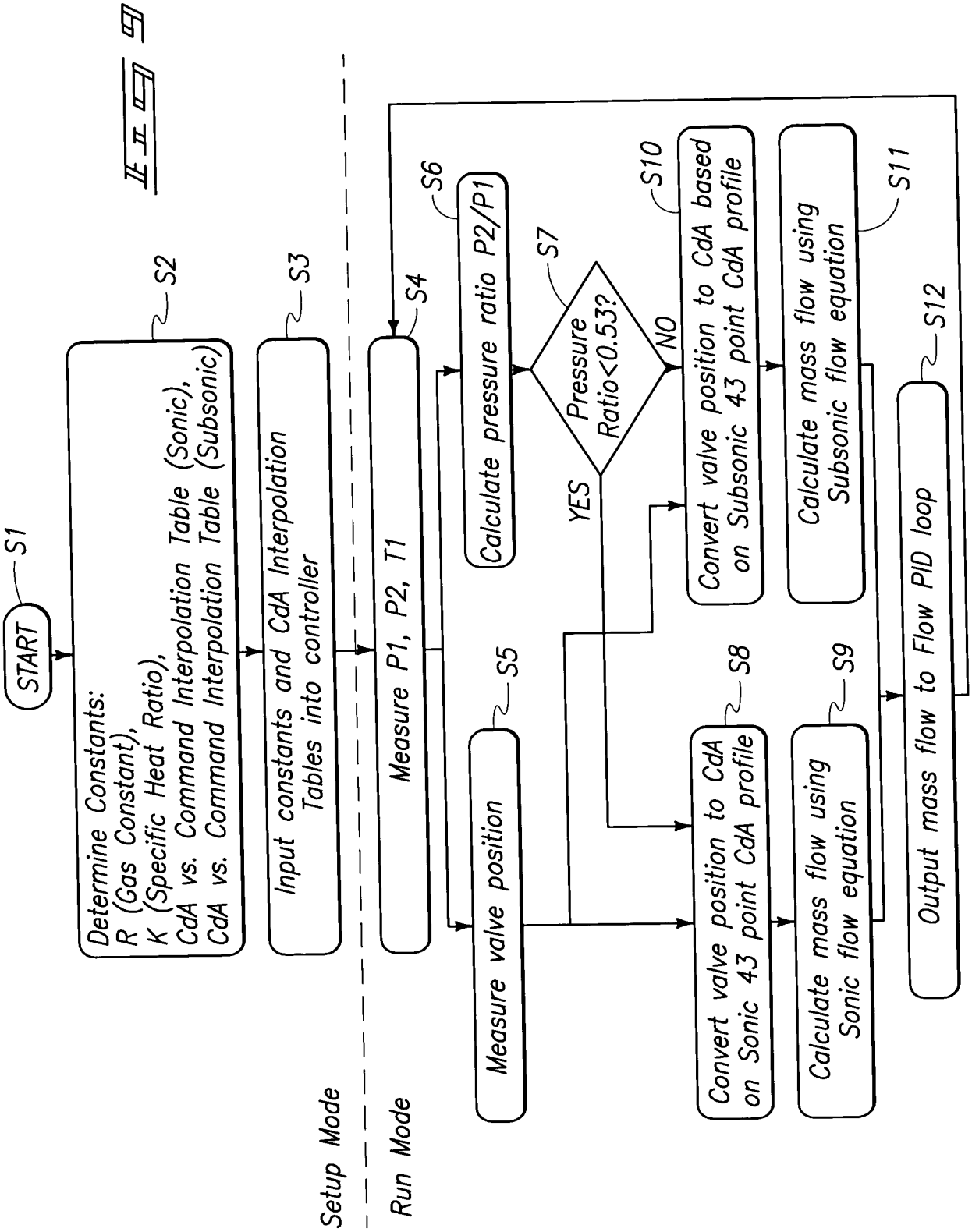
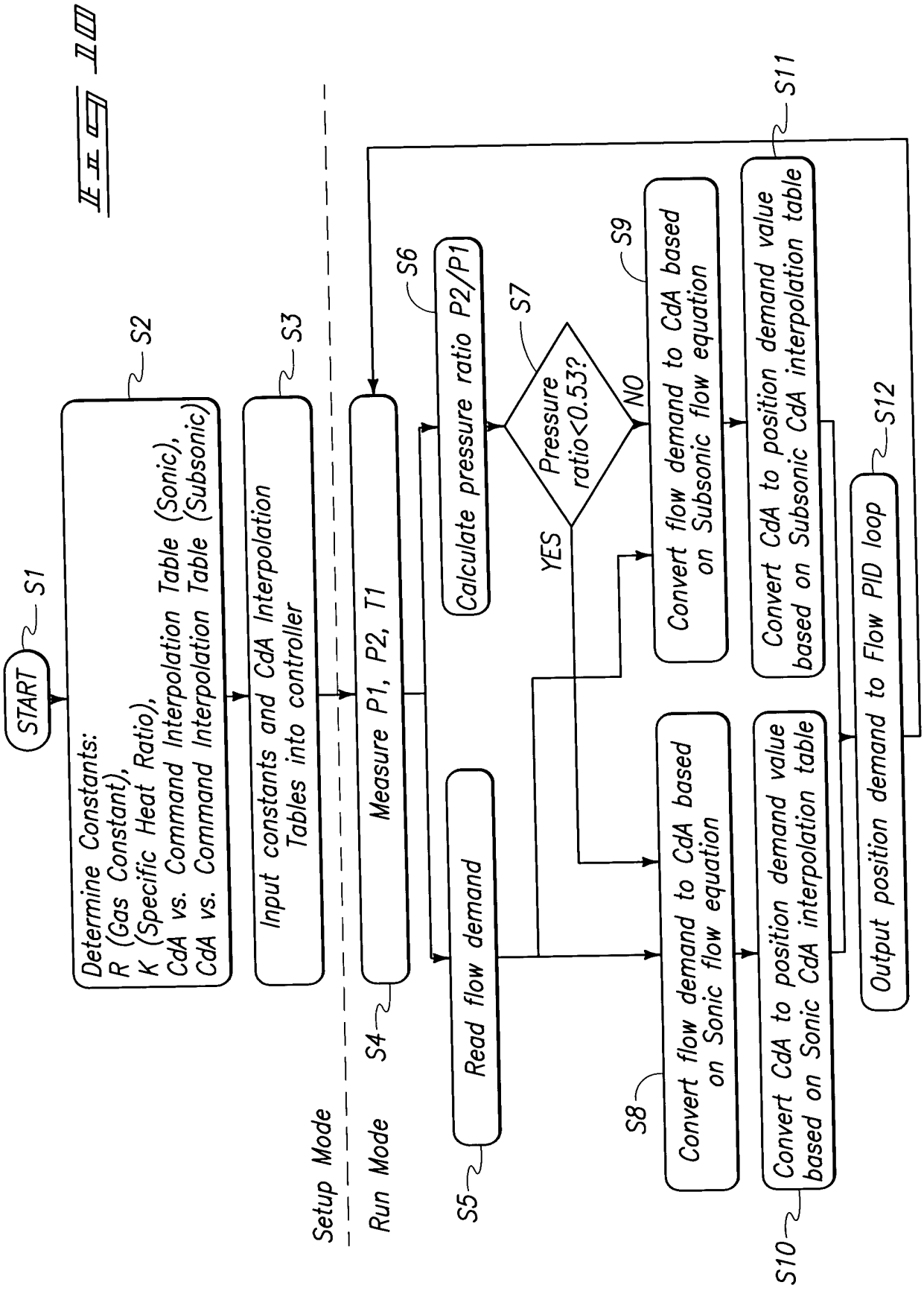

START
S1
Determine Constants:
R (Gas Constant),
K (Specific Heat Ratio),
CdA vs. Command Interpolation Table (Sonic),
CdA vs. Command Interpolation Table (Subsonic)
S2
Input constants and CdA Interpolation Tables into controller
S3
Setup Mode
Run Mode
Measure P1, P2, T1
S4
Measure valve position
S5
Calculate pressure ratio P2/P1
S6
Pressure Ratio<0.53?
S7
YES
NO
Convert valve position to CdA on Sonic 43 point CdA profile
S8
Calculate mass flow using Sonic flow equation
S9
Convert valve position to CdA based on Subsonic 43 point CdA profile
S10
Calculate mass flow using Subsonic flow equation
S11
Output mass flow to Flow PID loop
S12

FIG 9

Fig 3


START
S1
Determine Constants:
R (Gas Constant),
K (Specific Heat Ratio),
CdA vs. Command Interpolation Table (Sonic),
CdA vs. Command Interpolation Table (Subsonic)
S2
Input constants and CdA Interpolation Tables into controller
S3
Setup Mode
Run Mode
Measure P1, P2, T1
S4
Read flow demand
S5
Calculate pressure ratio P2/P1
S6
Pressure ratio<0.53?
S7
YES
NO
Convert flow demand to CdA based on Sonic flow equation
S8
Convert flow demand to CdA based on Subsonic flow equation
S9
Convert CdA to position demand value based on Sonic CdA interpolation table
S10
Convert CdA to position demand value based on Subsonic CdA interpolation table
S11
Output position demand to Flow PID loop
S12

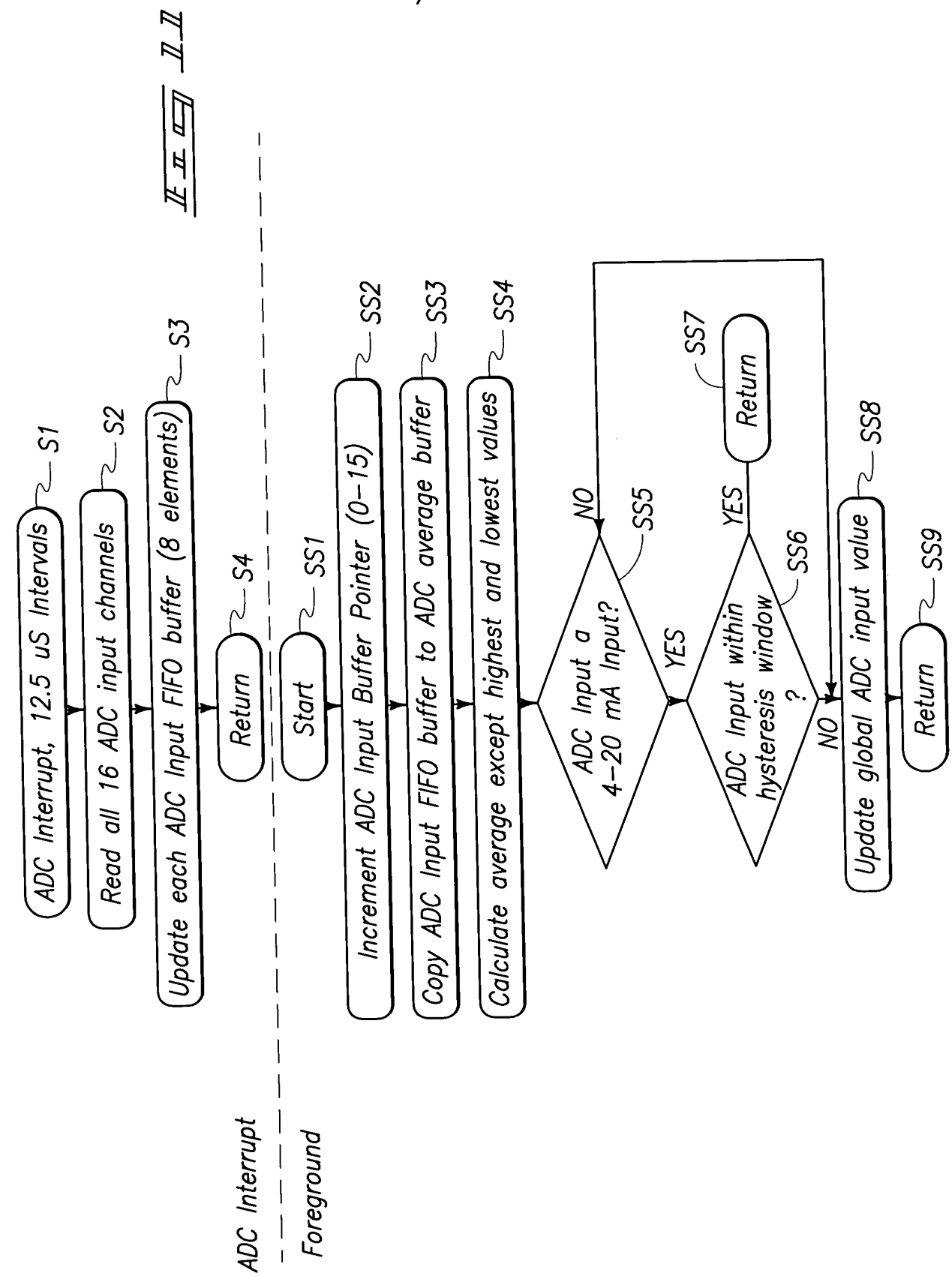
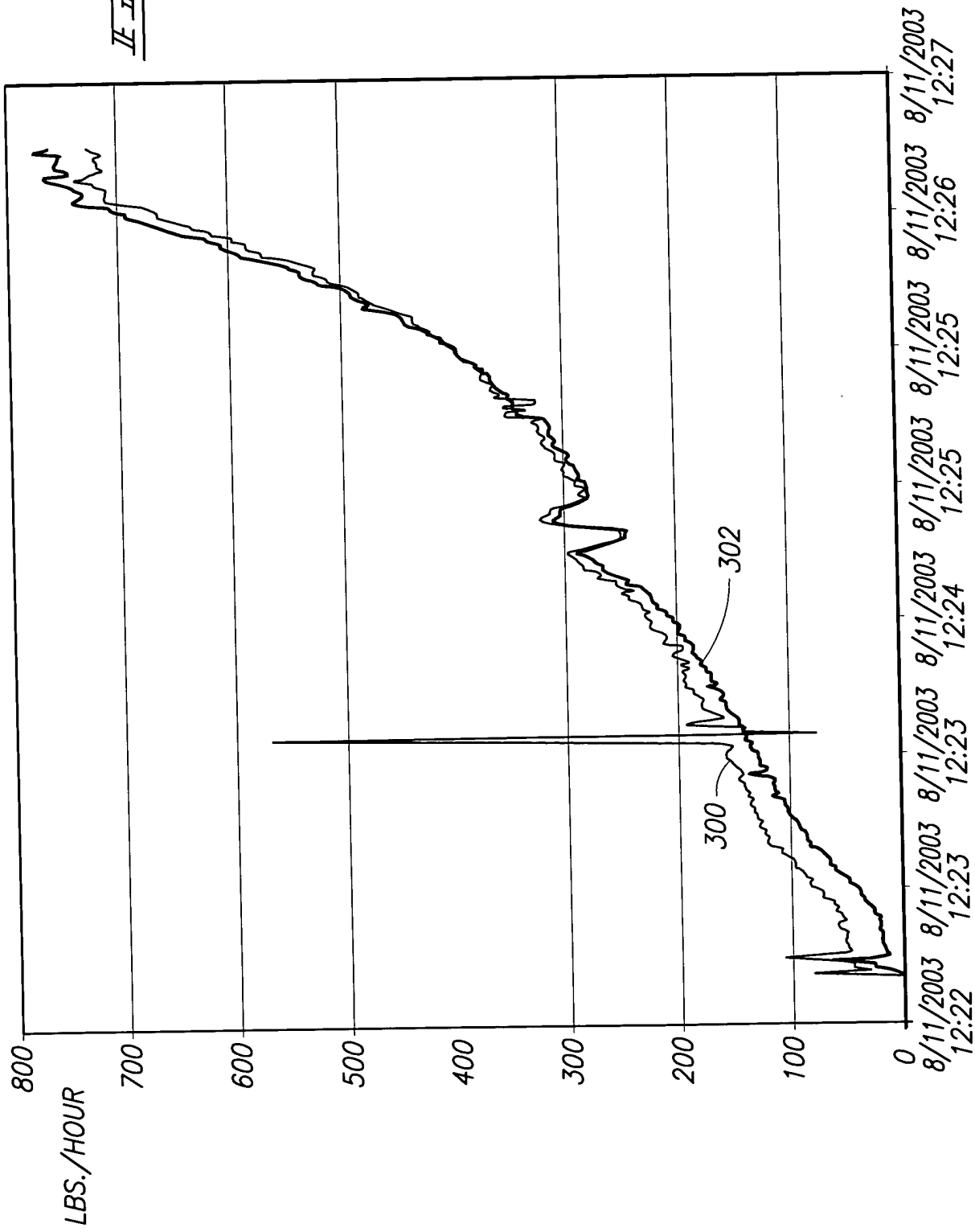

ADC Interrupt, 12.5 uS Intervals
S1
Read all 16 ADC input channels
S2
Update each ADC Input FIFO buffer (8 elements)
S3
Return
S4
ADC Interrupt
Foreground
Start
SS1
Increment ADC Input Buffer Pointer (0-15)
SS2
Copy ADC Input FIFO buffer to ADC average buffer
SS3
Calculate average except highest and lowest values
SS4
ADC Input a 4-20 mA Input?
SS5
NO
YES
ADC Input within hysteresis window ?
SS6
YES
NO
Return
SS7
Update global ADC input value
SS8
Return
SS9

FIG II

FIG 12


LBS./HOUR
800
700
600
500
400
300
200
100
0
8/11/2003 12:22
8/11/2003 12:23
8/11/2003 12:23
8/11/2003 12:24
8/11/2003 12:25
8/11/2003 12:25
8/11/2003 12:26
8/11/2003 12:27
300
302